Damage Simulations in Hard and Deeply Buried Targets due to Internal Blast and Shock Loading

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Executive Summary

The counterproliferation of Weapons of Mass Destruction (WMD) is one of our nation's highest defense priorities. Technologies are needed to defeat an expanding list of WMD targets including surface, mobile, and deeply buried targets. Hardened and deeply buried targets (HDBTs), namely tunnels, present the greatest challenge. They cannot be physically defeated with current conventional munitions. Hence, a variety of weapons options and damage or functional-kill mechanisms have to be evaluated. One of the options is to attack the tunnel portals with weapons that penetrate into or through the thinner cover rock above the portal or through the exterior doors, resulting in an internal detonation. This internal detonation generates a severe airblast environment within the tunnel system. Airblast propagation within a confined area, such as a tunnel, is significantly increased over that found in the open air. If the airblast environment is sufficiently severe, considerable damage to the equipment used in the production or delivery of WMD can be achieved.

The layout of a deeply buried hardened tunnel may vary significantly from long, straight tunnels to the ones with multiple intersections, expansions, constrictions, chambers, rooms, alcoves, and multiple levels. It is impractical to conduct field tests to cover all the possible tunnel configurations. Current semi-empirical models are limited with regard to tunnel geometry and weapon location. Sophisticated numerical models that can accommodate the complex geometry are required to accurately predict the airblast environment in tunnels. The size and complexity of the models needed to make these assessments will require the use of high-performance computing resources. Hence, this research will address development and validation of computational methods on scalable computers for assessing the damage of various deeply buried hardened target configurations. This research is essential in developing semi-empirical models for future weapon development and mission planning software.

The Joint Warfighting S&T Plan Counterproliferation objective specifically includes counterforce defeat of hardened WMD storage and production facilities. Defeat of underground targets was a top priority as defined by the warfighting Counterproliferation Program Review Committee Report to Congress.

1. Introduction

The counterproliferation of Weapons of Mass Destruction (WMD) is one of our nation's highest priorities. Since the Gulf War, many nations are concealing critical military assets in hardened and deeply buried targets (HDBTs), namely tunnels in rock. Most of these facilities are so deep that the developmental and current inventory weapons cannot penetrate to sufficient depths to directly destroy critical assets. One of the warfighter's options is to attack the tunnel portals with weapons that penetrate the thinner layer of rock above the portal, or though the exterior doors, resulting in a detonation within the tunnel system. Penetrations through the door systems have the potential to place the warheads deep within the facility. Detonations within a tunnel, even only in a few diameters, have a significant increase in airblast propagation into the facility compared to external detonations. Tunnel layouts range from long, straight tunnels to various types of intersections, expansions, constrictions, chambers, rooms, alcoves, and multiple levels. All of these configurations affect the propagation of airblast.

Airblast propagation within a tunnel system has the potential to cause significant damage to critical equipment and systems. If the critical equipment within a facility can be damaged or destroyed, then the function of the facility can be degraded or destroyed, resulting in a functional kill. Depending on the purpose of the facility and the level of damage, a functional kill can be as permanent as a "structural kill," in which the facility is destroyed in a more traditional manner.

Functional kill from airblast loads is predicated on the ability to accurately determine the blast environment from an internal detonation. The response of critical equipment cannot be calculated without accurate blast loads. Unlike free-field blast loads, a detonation within a tunnel system can have a significant dynamic pressure component. This dynamic pressure component, in conjunction with the overpressure component, makes up the entire pressure-loading history necessary to predict component response.

2. Justification/DOD Relevance

Technologies are lacking for target characterization and conventional defeat or functional kill of deeply buried hardened targets. The Joint Warfighting S&T Plan Counterproliferation objective specifically includes counterforce defeat of hardened WMD storage and production facilities. Defeat of underground targets was a top priority as defined by the warfighting Counterproliferation Program Review Committee Report to Congress. The proposed work is directly in support of the above activity.

Field testing of deeply buried hardened targets, such as tunnels in rock, is impractical. Available semi-empirical models are inadequate for developing damage assessment methods for deeply buried hardened targets, such as complex tunnel geometries in rock, against internal explosions. Hence, validated numerical methods on scalable computers are needed for assessing the damage of various deeply buried hardened target configurations. The complexity and size of this problem require the use of scalable computers to accurately predict internal blast propagation and to develop damage assessment methods.

3. Technical Approach

3.1 Objective

The overall objective of this research is to develop validated numerical methods on high-performance computers for assessing damage of various deeply buried hardened target configurations against internal explosions. Detonations within a tunnel system will have a significant increase in airblast propagation into the facility compared to external detonations, and the associated dynamic pressure component will play a key role for functional kill. In addition to modeling explosion and blast wave propagation in complex tunnel geometric configurations, modeling the behavior of surrounding geologic materials and equipment involved in WMD production or delivery is an important aspect of the study. The response of critical equipment and components (such as blast doors, missile bodies, WMD containers, and infrastructure systems) is pivotal to determining damage within the tunnel. These computational methods will assist the warfighter in assessing functional kill of deeply buried hardened tunnel systems used for WMD due to an internal explosion.

3.2 Challenge Project Team

Some of the key DOD and DOE players who will be working on this HPC Challenge Project are:

Dr. Raju R. Namburu, CEWES
Mr. Gordon W. McMahon, CEWES
Mr. Byron Armstrong, CEWES
Mr. Tommy Bevins, CEWES
Ms. Sharon Garner, CEWES
Dr. Gene Hertel, Sandia National Laboratory
Dr. Carol Hoover, Lawrence Livermore National Laboratory

3.3 Schedule

To assess damage in hardened and deeply buried targets due to internal blast and shock loading; the Challenge Project will address the following during the years 1999 and 2000.

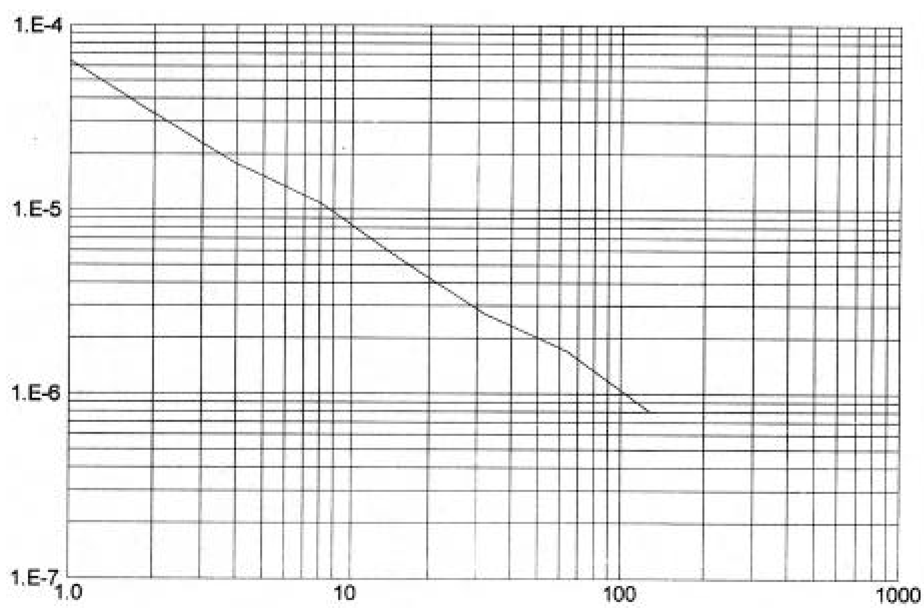
Year 1999

- Validate computational methods with the available experimental data.
- Develop and validate constitutive models and damage models for specific geologic materials.

Year 2000

- Conduct a series of simulations for tunnel systems based upon charge size, tun dimensions, tunnel geometry, and charge location.
- Develop attenuation parameters for overpressure and dynamic pressure for various tunnel intersections and configurations.

[illegible] of mass, momentum, and energy equations. A wide variety of materials may be modeled, including high explosives, energy sources, elastic-plastic materials, and geologic materials including fracture. The remap step uses second-order accurate algorithms to map the database on the distorted mesh at the end of Lagrangian step back to the original Eulerian mesh using a second-order van Leer advection scheme. Further, it uses an operator splitting scheme along with an optional high-resolution material interface reconstruction technique to complete the remap.



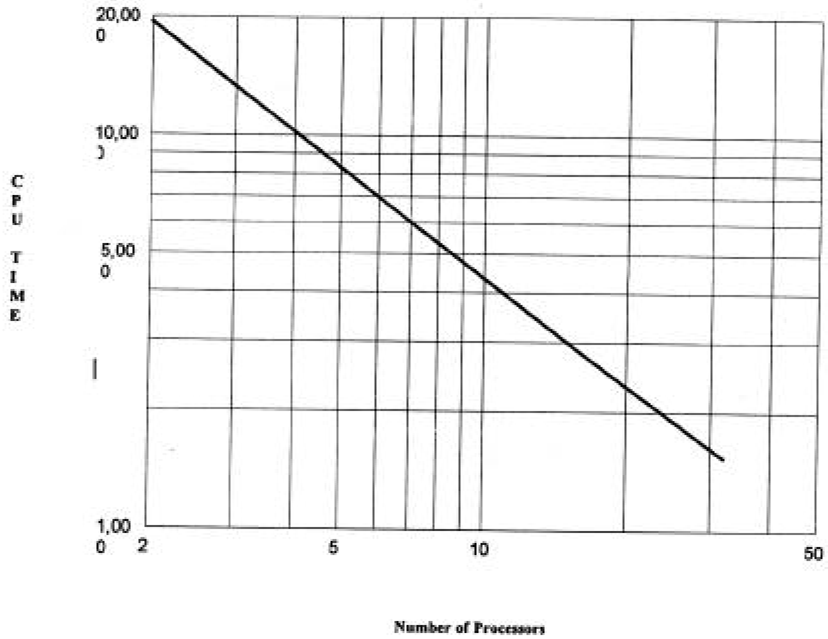


Figure 2. Scalable performance of ParaDyn for a contact interface application.

5. Required Resources and Justification

Typical size of each computational run for FY99-00 is given in the following table:

	Eulerain	Larangian
Number of cells/elements	50E+06 to 60E+06	3E+06 to 5E+06
Number of materials	6	5
Number of runs	25	20

Based on our past experience with DoD HPC Challenge Projects, to solve 80E+06 , Eulerian equations with five materials, it took about 60,000 processor hours on a Cray T3E to simulate 15 milliseconds simulation. Similarly, for solving 5E+06 Lagrangian equations, with four materials, it took about 8,000 processor hours on a Cray T3E. Based on the performance studies of the software, it takes slightly longer to solve the above Eulerian problem on an IBM SP than on a Cray T3E. The estimates shown in tables in the summary section are projections of the discussed runs.

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DoD Challenge Project Resource Request
Section I: Project Leader Identification

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Section II: Resource Requirements

FY 1999

Platform(s)	Location		CPU Resources (processor-hours)	
	First Choice	Second Choice	Request	Minimum Acceptable
Cray T3E	CEWES	NAVO	200,000	150,000
IBM SP	CEWES		10,000	100,000
O2K	CEWES	ARL	25,000	25,000

FY 2000

Platform(s)	Location		CPU Resources (processor-hours)	
	First Choice	Second Choice	Request	Minimum Acceptable
Cray T3E	CEWES	NAVO	250,000	200,000
IBM SP	CEWES		250,000	200,000
O2K	CEWES	ARL	50,000	50,000

Platforms	Typical Job Memory Requirement (GB)	Maximum Job Memory Requirement (GB)	Typical Job Secondary Storage Requirement (GB)	Maximum Job Secondary Storage Requirement (GB)
T3E	40 (GB)	60 (GB)	200 (GB)	500 (GB)
IBM SP	60 (GB)	80 (GB)	300 (GB)	600 (GB)
O2000	16 (GB)	32 (GB)	20 (GB)	40 (GB)

Section III: Project Summary

DoD Challenge Project Title: Damage Simulations in Hard and Deeply Buried Targets due to Internal Blast and Shock Loading

Related Requirements Project Title(s): Survivability and Protective Structures

Requirements Project Number(s):____